Therese McAllister
David Biggs
Edward M. DePaola
Dan Eschenasy
Ramon Gilsanz

7 Peripheral Buildings

7.1 Introduction

In addition to the WTC buildings and Bankers Trust building, a number of other buildings suffered damage from the projectiles and debris resulting from the deliberate aircraft impacts into WTC 1 and WTC 2 on September 11, 2001, and the resulting collapse of WTC 1, WTC 2, and WTC 7. As discussed in Chapter 1, Section 1.4, on September 12, 2001, the first round of building inspections were contracted for the New York City Department of Buildings (DoB) and the New York City Department of Design and Construction (DDC). This chapter is based on the field observations made by the Building Performance Study (BPS) Team, the Structural Engineers Association of New York (SEAoNY) summary presented below, and *Life Safety Reports* prepared by LAZ Technology/Thornton-Tomasetti (LZA 2001).

The building assessments were compared and coordinated with a parallel inspection performed by DoB and are summarized in Figure 7-1 and Table 7.1 according to the following color coding:

Green	Inspected	No significant damage found.
Yellow	Moderate Damage	Broken glass, façade damage, roof debris.
Blue	Major Damage	Damage to structural members requiring shoring or significant danger to occupants from glass, debris, etc.
Red	Partial Collapse	Building is standing, but a significant portion is collapsed. All of these buildings were inspected and found to have no remaining certifiable structural capacity.
Black	Full Collapse	Building is not standing.

It is important to note the distinction between evaluations for occupancy, access, and life safety and those for structural safety. Extensive damage to glazing and façades may pose a significant threat to the public, but there may be no structural damage. "Major Damage" has both of these types of damage. Because this report is concerned with building performance, primarily structural and fire performance, major damage categories that do not include structural or fire damage are not specifically addressed. The following buildings suffered the most severe collateral damage from the collapse of the WTC towers:

Major Damage (shoring and large debris removal required):

WFC 3, American Express

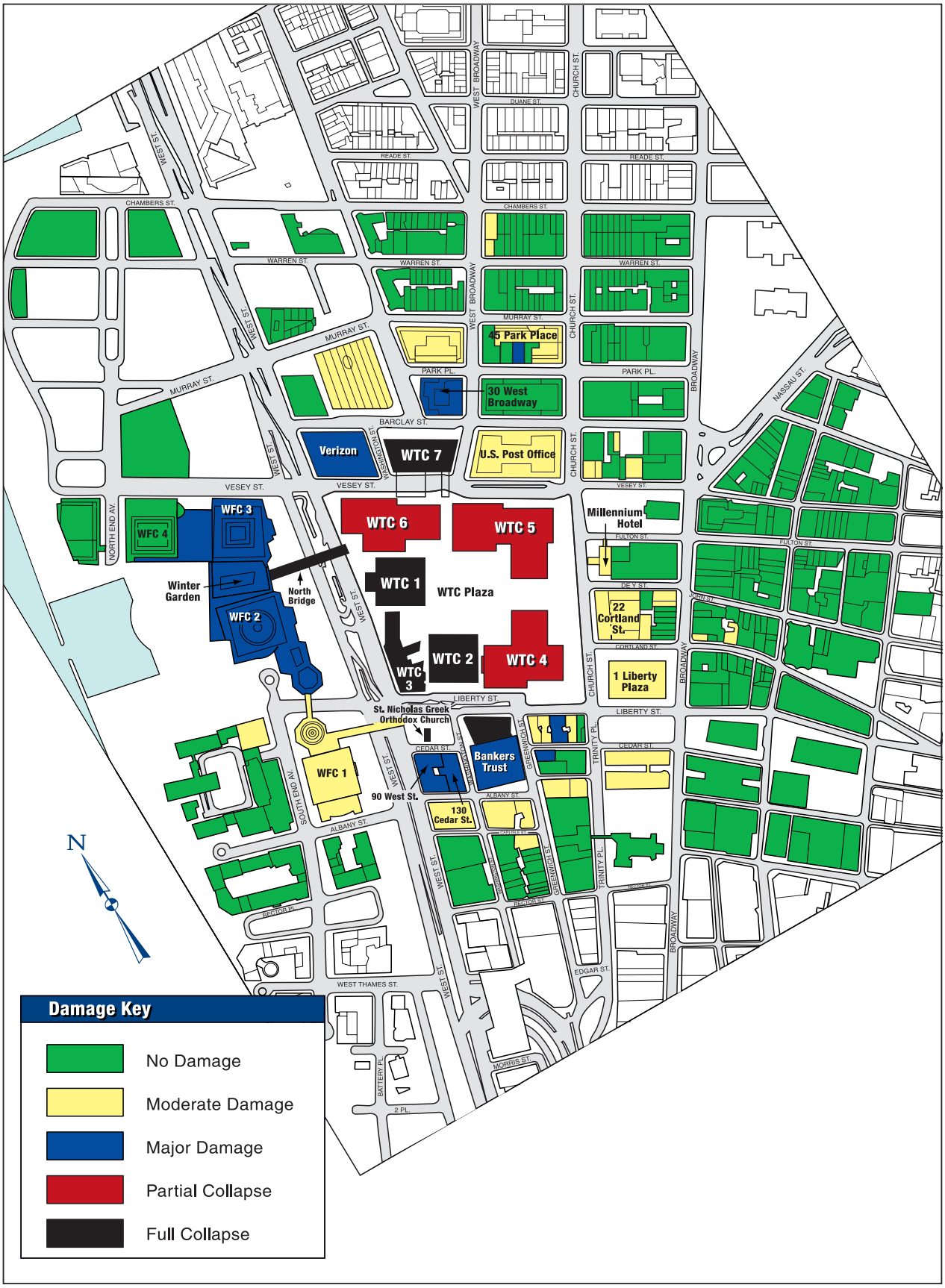

Figure 7-1 New York City DDC/DoB Cooperative Building Damage Assessment Map of November 7, 2001 (based on SEAoNY inspections).

Table 7.1 DoB/SEAoNY Cooperative Building Damage Assessment – November 7, 2001[1]

No.	Block	Lot	Address	Name	Building Color Code[2]	Building Rating
1	16	100	395 South End Ave.	Gateway	Yellow	Moderate Damage
2	16	120	120 West St.	1 WFC Tower A	Yellow	Moderate Damage
3	16	120	120 West St.	South Bridge	Yellow	Moderate Damage
4	16	120	120 West St.	1-2 WFC Link Bridge	Yellow	Moderate Damage
5	16	125	125 West St.	2 WFC Tower B	Blue	Major Damage
6	16	140	200 Vesey St.	3 WFC Tower C - Annex	Blue	Major Damage
7	16	140	201 Vesey St.	Winter Garden Building	Blue	Major Damage
8	48	1	2 Wall St.		Yellow	Moderate Damage
9	49	2	111 Broadway		Yellow	Moderate Damage
10	51	14	125 Greenwich St.		Yellow	Moderate Damage
11	51	15	90 Trinity Pl.		Yellow	Moderate Damage
12	52	10	120 Cedar St.		Blue	Major Damage
13	52	15	110 Trinity Pl.		Yellow	Moderate Damage
14	52	21	120 Liberty St.		Yellow	Moderate Damage
15	52	22	124 Liberty St.	Fire Station	Yellow	Moderate Damage
16	52	30	106 Liberty St.		Yellow	Moderate Damage
17	52	7501	110 Liberty St.		Yellow	Moderate Damage
18	52	7502	114 Liberty St.	Engineering Building	Blue	Major Damage
19	53	23	5 Carlisle		Yellow	Moderate Damage
20	53	28	1 Carlisle		Yellow	Moderate Damage
21	53	33	110 Greenwich St.		Yellow	Moderate Damage
22	54	1	130 Liberty St.	Bankers Trust	Blue	Major Damage
23	56	1	130 Cedar St.		Blue	Major Damage
24	56	20	155 Cedar St.	Greek Orthodox Church	Black	Collapse
25	56	4	90 West St.		Blue	Major Damage
26	58		WTC 1	North Tower	Black	Collapse
27	58		WTC 2	South Tower	Black	Collapse
28	58		WTC 3	Marriott International Hotel	Black	Collapse
29	58	1	WTC 4	South East Plaza	Red	Partial Collapse
30	58	1	WTC 5	North East Plaza	Red	Partial Collapse
31	58	1	WTC 6	Custom House	Red	Partial Collapse
32	84		WTC 7		Black	Collapse
33	62	1	1 Liberty Plaza		Yellow	Moderate Damage
34	63	1	10 Cortland St.		Yellow	Moderate Damage
35	63	3	22 Cortland St.		Yellow	Moderate Damage
36	63	6	27 Church St.	Century 21	Yellow	Moderate Damage
37	63	13	189 Broadway		Yellow	Moderate Damage
38	63	15	187 Broadway		Yellow	Moderate Damage
39	65	10	9 Maiden Ln.	Jeweler's Building	Yellow	Moderate Damage
40	65	16	174 Broadway		Yellow	Moderate Damage
41	80	4	47 Church St.	Millennium Hotel	Yellow	Moderate Damage
42	84	1	140 West St.	Verizon	Blue	Major Damage
43	86	1	90 Church St.	Post Office	Yellow	Moderate Damage
44	88	2	12 Vesey St.		Yellow	Moderate Damage
45	88	8	26 Vesey St.		Yellow	Moderate Damage
46	88	10	28 Vesey St.		Yellow	Moderate Damage
47	88	13	14 Barclay St.		Yellow	Moderate Damage
48	125	20	100 Church St.		Yellow	Moderate Damage
49	126	2	110 Church St.		Yellow	Moderate Damage
50	126	9	45 Park Pl.		Blue	Major Damage
51	126	27	120 Church St.		Yellow	Moderate Damage
52	127	1	30 West Broadway		Blue	Major Damage
53	127	18	75 Park Pl.		Yellow	Moderate Damage
54	128	2	224 Greenwich St.		Yellow	Moderate Damage
55	136	15	60 Warren St.		Yellow	Moderate Damage
56	136	16	128 Chambers St.		Yellow	Moderate Damage

[1] Adapted from SEAoNY inspections of September and October 2001 – Building Ratings and Actions table.

[2] Based on DDC/SEAoNY inspections of September and October 2001 and DoB inspections of October 22, 2001.

Verizon

30 West Broadway

45 Park Place

Bankers Trust

90 West Street

130 Cedar Street

Partial Collapse

WTC 4

WTC 5

WTC 6

Winter Garden building (later revised to Major Damage)

Full Collapse

WTC 3

WTC 7

North Bridge from Winter Garden to WTC 1

St. Nicholas Greek Orthodox Church

Damage to the WTC and Bankers Trust buildings has been covered in previous chapters, and no inspection was made of St. Nicholas Greek Orthodox Church, because it was completely destroyed by falling debris. The damage to and performance of the remaining buildings is briefly presented. Immediately after the collapse of the towers, One Liberty Plaza was reported to be near collapse, but was later found to have no structural damage. The events leading up to this misunderstanding are briefly discussed.

7.2 World Financial Center

The World Financial Center (WFC) complex is located immediately west of the WTC Plaza, and includes four office towers, pedestrian walkways, and the Winter Garden (Figure 7-1). The buildings are of contemporary construction dating from 1985 to the present, have large floor plans, and are steel-framed structures with granite-clad curtain wall facades.

These buildings sustained varying degrees of façade and structural damage from the debris, with the eastern elevations experiencing the heaviest damages. The north and south elevations sustained lesser debris damage. WFC 1, 2, and 3 suffered glazing and façade damage, but WFC 4 was undamaged. Debris and dust penetrated nearly the full floor areas of WFC 2 and WFC 3 at several levels.

7.2.1 The Winter Garden

The Winter Garden lies between WFC 2 and WFC 3. It is a large greenhouse structure with a glass and steel telescopic barrel vault roof and is one of the largest public spaces in New York. The structure covers an area of approximately 200 feet by 270 feet and includes a public space of 120 feet by 270 feet. The largest vault has a clear height of about 130 feet and a span of 110 feet. The west elevation is made entirely of glass panels. The east end of the building has five composite steel floors that support a glass dome that covers a ceremonial stair. The structure has expansion joints where it meets WFC 2 and WFC 3. The spatial stability of the frame is insured by trussed arch framing. The east end was linked to the WTC complex by the North Bridge, which had a 200-foot clear span and was 40 feet wide. The west end has an entrance door.

Columns from WTC 1 hit the east end of the structure, particularly the area directly adjacent to the North Bridge. The Winter Garden experienced severe collapse of the eastern end framing. Several other semicircular trusses and parts of the dome were also badly damaged. The western two bays of the roof structure remained intact, but were covered with debris. Inspectors estimated that 60 percent of the roofing glass panels of the structure had collapsed.

Additional structural collapse occurred on parts of the 2nd and 3rd floor framing adjacent to WFC 2 and WFC 3, the North Bridge connection extension, the ceremonial stair above the circular landing, and the 4th and 5th floors at the eastern end. Localized structural collapse occurred in various other areas of the barrel roof.

As the eastern roof trusses were sheared in several places, support was provided only by the transverse plate girders that remained in place. These conditions, coupled with the shearing of trussed arch framing, led the first round of inspectors to conclude that the structure was potentially unstable, and a rating of Partial Collapse was assigned. After installation of shoring, a new evaluation of the building led engineers to determine that the building was repairable, and the rating was revised to Major Damage.

7.2.2 WFC 3, American Express Building

The 50-story WFC 3 building has a plan area of approximately 200 feet by 250 feet. Exterior column trees from WTC 1 were found hanging from the southeast corner of WFC 3 (Figure 7-2) and on the setback roof and against the east face of the Winter Garden (Figures 7-3 and 7-4). The impact of exterior column trees caused structural damage in both structures. Building faces not directly oriented toward the WTC site suffered minimal damage, even at the close proximity of several hundred yards.

Figure 7-2
Southeast corner of WFC 3.

OEM

Figure 7-3
View of Winter Garden damage from West Street, with WTC 1 debris in front of WFC 2.

Figure 7-4
View of Winter Garden damage from West Street, with WTC 1 debris leaning against WFC 3.

The glazing and façade damage in the building was similar to that found in WFC 1 and WFC 2, which also had extensive cracking and breakage of glazing and granite panels. Debris from WTC 1 caused a collapse of the top 8 stories of the 10-story octagonal extension located at the southeast side of the building. The main WFC 3 building suffered damage from floors 17 to 26. A three-story section of exterior column trees from WTC 1 hung from the base of the collapsed area at floor 20, as shown in Figure 7-2, with approximately 25 feet of the column hanging outside the building. At floors 17 through 26, the corner column had been removed by the impact of debris, and the floors cantilevered from adjacent columns to the north and west. Smaller column debris penetrated floor 17. The damage did not extend past the corner bay, which had to be shored and was later demolished.

Interior damage is shown in Figure 7-5. Inspection of the interior determined that steel framing members that sustained direct impact from large debris had significant portions of the cementitious fireproofing material knocked off. The fireproofing was intact on adjacent steel members that had not been directly hit.

The localized nature of the damage, given the size of projectiles that impacted the building, is notable. Observations noted small welds between column end bearing plates at exterior and interior columns, indicating the columns near the damage zone were designed for gravity loads, and tension loads from wind were not a critical design parameter. This type of connection between columns may have allowed a column member to be knocked out of place without causing substantial displacement or damage to connecting framing.

7.3 Verizon Building

The Verizon building is located on the block bounded by Barclay Street on the north, Washington Street on the east, Vesey Street on the south, and West Street on the west. It is north of WTC 1 and WTC 2, and immediately west of WTC 7, which all collapsed.

Figure 7-5 Interior damage at floor 20 of WFC 3.

The 30-story Verizon building was built in the 1930s and has a steel frame with infill exterior walls of unreinforced masonry, and five basement levels. The steel frame is encased in cinder-concrete and draped-wire-mesh, with cinder-concrete slab floor construction. Beams are rolled sections (mostly 12 inches deep) with cover plates at floors with high live loads. Girders are either rolled sections or built up from plates and angles. Columns are also built-up sections. Partially restrained moment frames at the building perimeter provide lateral resistance. The masonry walls are about 12 inches thick (on average), and the columns are encased in brick. The façade and 1st floor lobby are registered as historic landmarks. At the time of the adjacent building collapses, the Verizon building was in the midst of an extensive façade restoration program.

The proximity of the building to WTC 2 resulted in considerable damage to the south and east faces of the building. Damage included collapsed floor slabs and deformed beams and columns, including some local buckling. Window damage was moderate, and it is notable that the windows contained wire mesh. The west (West Street) and north (Barclay Street) sides of the building were not damaged.

The east (Washington Street) side of the building was damaged from about the 9th floor down, primarily due to the impact of debris sliding out from the base of WTC 7 (Figures 7-6, 7-7, and 7-8). Some damage may have also been caused by WTC 1 debris. In addition to fairly extensive façade damage (bricks and windows), there was damage to two bays of slab and framing at the 1st, 4th, and 7th floors and to one bay of slab and framing (including spandrel beam) at the 1st floor mezzanine and at the 5th floor. Two exterior columns suffered major damage between the 1st and 2nd floors (Figure 7-9), one exterior column suffered minor damage between the 3rd and 5th floors, and two exterior columns suffered major damage between the 6th and 8th floors. In addition, one interior column suffered minor damage below the 7th floor.

Figure 7-6
Verizon building – damage to east elevation (Washington Street).

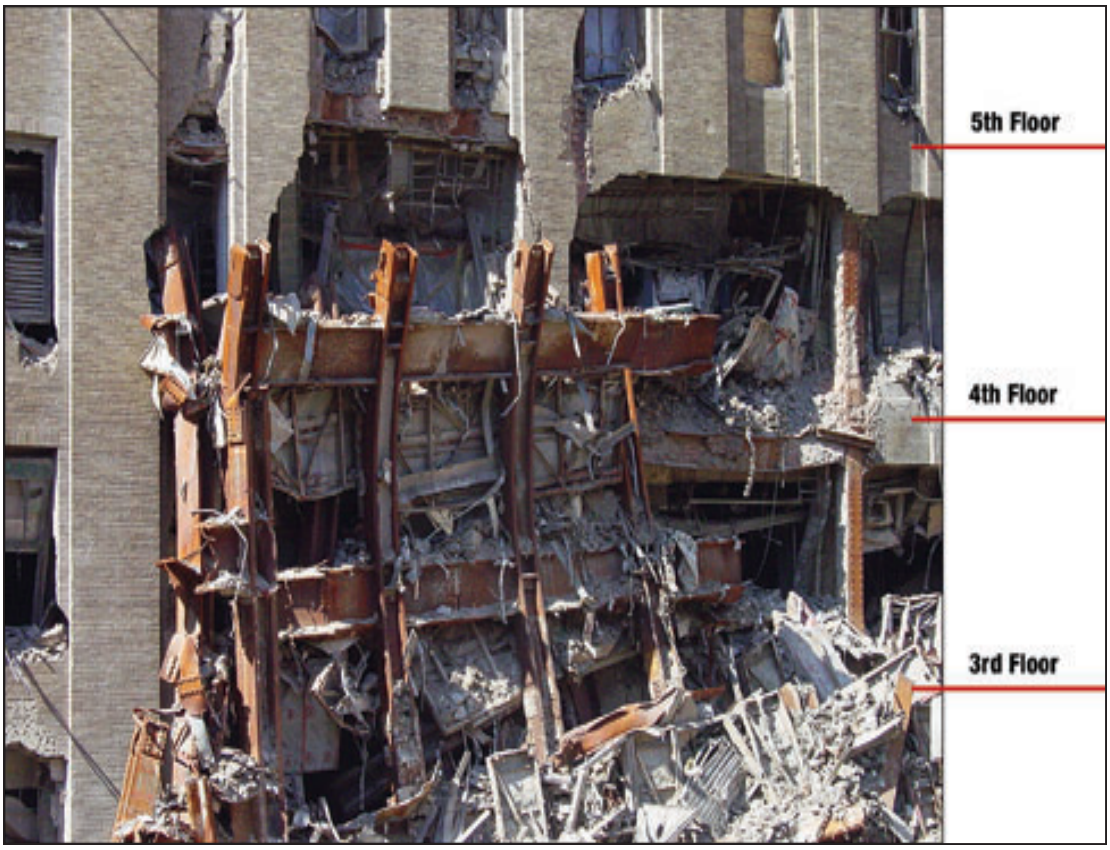

Figure 7-7 Verizon building – damage to east elevation (Washington Street) due to WTC 7 framing leaning against the building.

Figure 7-8 Verizon building – damage to east elevation (Washington Street).

Figure 7-9 Verizon building – column damage on east elevation (Washington Street).

The south (Vesey Street) side of the building was damaged from approximately the 13th floor down, primarily due to the impact of projectile debris from the collapse of WTC 1 (Figure 7-10). In addition to fairly extensive façade damage (bricks and windows), two bays of slab and framing were damaged at the sidewalk arcade at the 1st floor, and one bay of slab and framing (including spandrel beams) was damaged at the 6th, 7th, 9th, 11th, 12th, and 13th floors (Figures 7–11 and 7-12). In addition, one interior column suffered minor damage below the 1st floor.

None of the damage to the floor framing threatened the structural integrity of the building. Although the damaged columns were deflected out-of-plane, it was determined that the columns were stable and not in danger of imminent collapse.

In general, the Verizon building performed well, especially given its close proximity to WTC 7. On the south (Vesey Street) side of the building, damage was extremely localized near the point of impact of projectile debris. In some cases, only a short section of spandrel beam and small area of floor slab were damaged, leaving the remainder of the structural bay intact (Figure 7-12).

On the east (Washington Street) side of the building, most of the damage appeared to be due to the lateral pressure of the spreading debris at the base of WTC 7 (Figure 7-7). Two of the columns between the 1st and 2nd floors were deflected into the building by as much as 2 feet (with most of the rotation occurring at the column splice just above the 1st floor); at one of the columns, very little contact remained at the column splice (Figure 7-9). Even so, the columns did not buckle, and structural bays above did not collapse or deflect significantly. Similarly, the structural bays supported by the column between the 6th and 8th floors that was completely destroyed by the impact of projectile debris were essentially undamaged.

Figure 7-10
Verizon building – damage to south elevation (Vesey Street).

Figure 7-11 Verizon building – localized damage to south elevation (Vesey Street).

Figure 7-12 Verizon building – detail of damage to south elevation (Vesey Street).

Several factors may have contributed to the performance of the Verizon building. The thick masonry walls, brick-encased columns, and cinder-concrete-encased beams and girders probably absorbed much of the energy of the impacts while also providing additional stiffness and strength to the building frame. The lower floors (up to the 10th floor) were designed for either 150 pounds per square foot (psf) or 275 psf, depending on the intended occupancy. Consequently, the member sizes and end connections are unusually stocky. Although designed for higher-than-normal live loads, at the time of the adjacent building collapses, actual live loads were relatively low.

Most floors are framed with 12-inch-deep beams with cover plates, presumably to maintain uniform floor clearances. These sections had full lateral bracing and were probably able to develop close to their full plastic capacities without buckling. Almost every beam-column connection was nominally moment-resistant, making the structural system highly redundant. All of these characteristics combined to both absorb the energy of the debris impacts and provide alternate load paths around the damaged areas.

The performance of this building led to several observations. The original design was for a substantially heavier live load and use as a telephone switching facility. Even so, the exterior columns on the east side were substantially damaged at the lower floors by the collapse of WTC 7. The nominally 12-inch thick brick masonry perimeter walls absorbed a significant portion of the impact energy, resulting in less damage to the structural steel framing. Impact damage was localized and did not propagate beyond immediate points of impact (sometimes not even full bays were damaged). It was noted that the windows performed better than those in other peripheral buildings, likely due to the wire mesh.

7.4 30 West Broadway

The office structure at 30 West Broadway is most recently known as Fiterman Hall of the Borough of Manhattan Community College campus of the City University of New York. It is located just north of WTC 7. The 17-story building was constructed in the 1950s and has a concrete-encased structural steel frame with cinder-concrete floor slabs with draped steel mesh. The structure had riveted, bolted, and welded connections, and roof setbacks at the 6th and 15th floor levels. The curtain wall consists of horizontal bands of windows over glazed brick. There are continuous lintels at every floor. The building was in the final stages of rehabilitation work at the time of the terrorist attacks.

The southern half of the west façade and most of the south façade were severely damaged or destroyed. The south face of the building suffered structural damage in the exterior bay from impact by large debris from WTC 7 (Figure 7-13). There was no damage to the east and north faces of the building, and no fire in the building, even though there was a substantial fire in WTC 7.

Figure 7-13
30 West Broadway – south façade, 6th floor to roof, looking northeast.

Damage was concentrated along the south face at and below the setback at the 15th floor. Portions of the south façade from the 15th floor collapsed. A vertical section of the perimeter wall extending five floors down from the setback at the center of the south façade was raked away. Local collapse also occurred at the southwest corner. The majority of the glass panes were knocked out on the south façade, in a triangular pattern that extended to the full width of the base. The south side of the building was unstable and required bracing. Floors 9 through 14 had two collapsed bays, and floors 3 through 6 had up to three collapsed bays. No structural damage was observed one bay away from the impact damage.

Floors 9 through 14 had at least two collapsed exterior bays and floors 3 through 6 had at least three collapsed exterior bays. There was relatively little damage at the 7th floor. A considerable amount of debris was on the 8th floor. The steel beams supporting two bays of this floor yielded, but are still in place.

The building was impacted by debris from the collapse of WTC 7. Although structural damage from debris impact was contained to the exterior bays on the south side of the building and between roof setback levels, it was more extensive than that observed on the east side of the Verizon building.

7.5 130 Cedar Street

Constructed in the 1930s, the building at 130 Cedar Street is a 12–story reinforced concrete frame structure with setbacks at the 10th, 11th, and 12th floors (Figure 7-14). The building is directly east of 90 West Street and is bordered by Cedar Street to the north, Washington Street to the east, and Albany Street to the south.

The floor framing consists of reinforced concrete flat slabs supported on square columns with capitals and dropped slabs. Columns are spaced at approximately 16 feet on center in the east-west direction and approximately 21 feet on center in the north-south direction. Perimeter concrete spandrel beams beneath the windows and interior infill walls of brick, terra cotta, or concrete masonry provide additional lateral stiffness.

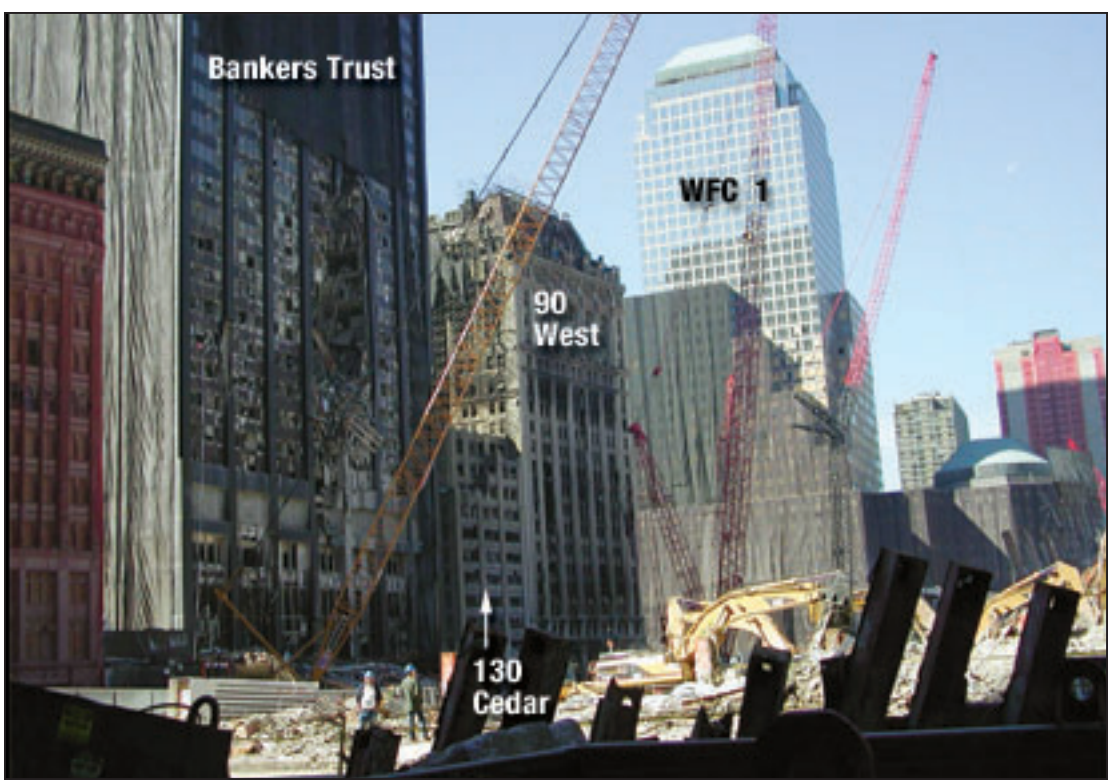

Figure 7-14 130 Cedar Street and 90 West Street.

Some façade damage was noted (primarily to the parapets), but most of the damage occurred at the roof level where the slab of the northeast corner collapsed under debris with the column capitals punching through the slab. A column section from WTC 2 penetrated the 10th floor roof slab. The southern portion of the building was not damaged. Structural damage from projectile impact and fire occurred primarily above the 9th floor. Fire damage was evident on the 11th and 12th floors in the northwest corner. Several concrete columns were cracked, possibly from the impact. Several bays at the northeast corner were severely damaged from debris impact. Concrete samples from two fire locations indicated that the concrete structure may have experienced fire temperatures of between 315 °C (600 °F) and 590 °C (1,100 °F). Spalling of capitals was observed in the fire areas.

The masonry infill walls were cracked throughout the building. It is not clear whether the condition pre-existed, or if it was due to the fire, floor settlement, or frame movement.

7.6 90 West Street

This building is located south of the WTC site, and adjacent to the 130 Cedar Street building located on the west side, as shown in Figure 7-14. The 24-story building has a steel-frame structure with a terra cotta flat-arch floor system and infill walls of unreinforced masonry. It was designed by architect Cass Gilbert and structural engineer Gunvald Aus in 1907. The floor plan has a skewed "C" configuration, with overall dimensions of approximately 124 feet by 180 feet. At the higher floors, the typical exterior wall assembly is terra cotta tiles on a brick wall. This building is a designated New York City landmark. In 1907, the building towered over the waterfront and warehouses in the area. Its top floor had a restaurant that was billed as the "world's highest."

The riveted steel framing consists of rolled and built-up sections for the columns and beams. Columns are spaced approximately 18 feet apart. The primary framing runs north-south, with secondary members in the east-west direction. Lateral load resistance is provided primarily by partial-strength, partially restrained moment connections of frame members and the infill masonry walls. The floor slabs of terra cotta flat arches appeared to be topped with low-strength cinder-concrete. Terra cotta and masonry enclosures provided fireproofing for all original architectural areas and structural elements. The building construction is shown in Figure 7-15

The New York City Building Code required the floors to be tested for 4 hours while exposed to a fire maintained at 927 °C (1,700 °F) and a load of 150 psf. Following the fire test, the fire-exposed underside was exposed to a fire hose stream with a nozzle pressure of 60 pounds per square inch (psi) for 10 minutes. The floor was then loaded and unloaded with a uniform load of 600 psf in the middle bay. The test was considered successful if the deflection of the beams supporting the assembly was less than 2.5 inches over a 14-foot length, after cooling.

The building was undergoing façade rehabilitation and was fully covered with scaffolding. Many of the interior columns still had the original terra cotta covers, and some were covered with plaster, but others were covered with sheet rock and intumescent paint, and, at one location, there was a metal deck with spray-on fireproofing. In some locations, spray-on cementitious fireproofing was used for later tenant work. Some scaffolding planks caught fire and may have contributed to the spread of the fire between floors.

Terra cotta and hollow-clay tile arches were common in fireproof office construction. Most of them were patented systems with 6- to 15-inch depths and spans from 54 to 90 inches. The arches were supported on the bottom flanges of steel beams. The bottom flanges of the supporting steel beams were generally protected by clay tile or terra cotta fireproofing. To provide a smooth finish, the arches were usually topped with a cementitious material that also protected the haunches of the steel beams. The arches had tie rods to resist the thrust of the arch. An 8-inch flat arch with hollow tile and a span of 6 feet could carry a safe load of

Figure 7-15 Interior of 90 West Street showing typical construction features.

170 psf (Kidder 1936). At 90 West Street, the tile floor arches usually span 6 feet. At lower floors, the tiles have a 12-inch thickness and cover the bottom flanges of the beams.

The roof was damaged by debris falling from WTC 2, and approximately half of the north face of the building experienced projectile impact and fire damage. WTC 2 projectiles severed spandrel beams at floors 8 to 11 in the 2nd bay from the west end, and in a middle bay at the 6th floor. Terra cotta slabs were damaged mostly in the exterior bay at these locations. In general, the projectiles damaged only the masonry and broke many terra cotta features. The damage to the interior structural terra cotta floor slabs was primarily due to the brittle fracture of the terra cotta slabs upon impact by large debris. Most of the damage was restricted to the two northernmost bays, with the exception of fire damage on the 1st through 5th, 7th through 10th, 14th, 21st, and 23rd floors. The fire did not spread to the south side of the building, except for the first 4 floors. Columns were buckled 1-2 inches on the 8th and 23rd floors, approximately a foot below the ceiling, as shown in Figures 7-16 and 7-17. A tube column supporting a north exit stair from the roof and a built-up column supporting the roof were the only other heat-induced buckling damage observed during initial inspections.

This type of construction, with terra cotta tiles providing fire protection, was common in early 20th century construction. The style of construction resulted in a highly compartmentalized building, which may have helped slow the spread of fire. The Fire Department of New York was able to control the fires in this building. The fire damage observed in the building, with minimal structural damage from a normal fire load, is considered typical for this type of construction and fire protection; however, it has been suggested that the scaffolding that was in place for renovations contributed to the spread of fire between floors that may not have occurred otherwise. However, the only structural damage observed was buckling damage near the tops of two columns.

Figure 7-16
Buckling damage at top of column on floor 8 of 90 West Street. Note the loss of fire protection at the top of the column.

7.7 45 Park Place

This building is located three blocks north of the WTC site (Figure 7-1), and was initially rated as No Damage when inspected from the exterior. However, subsequent interior inspection revealed that three floor beams were missing from the top story of the building as a result of the landing gear that penetrated the roof following the airplane impact on WTC 2, shown in Figure 1-4 (in Chapter 1). The rating was subsequently changed to Major Damage. No other significant damage was found.

7.8 One Liberty Plaza

One Liberty Plaza (One Liberty) is a 54-story, 730-foot-high building, comprising a footprint of 238 feet in the north-south direction by 163 feet in the east-west direction. The building area is approximately 2,000,000 square feet (Figures 7-18 and 7-19). It was designed by Skidmore, Owings, and Merrill in 1970 and served as corporate headquarters for U. S. Steel Corporation.

During the afternoon of September 11, following collapse of WTC 1 and WTC 2, rumors were spread that One Liberty was in imminent danger of collapse. This was due to a report by an untrained observer that the building face appeared to be moving or leaning.

Figure 7-17
Buckling damage at top of column on floor 23 of 90 West Street.

The majority of damage incurred at One Liberty consisted of broken window glass and frames. Most of that broken glass was in the lower six floors of the west-facing elevation, with less breakage on the floors above. There was, however, some broken glass on the north- and south-facing elevations as well. At those elevations, most of the broken glass was located at floors 1 through 6. There were approximately 550 broken lites of glass, and approximately 200 frames were damaged beyond repair.

On September 12, there was a persistent rumor that One Liberty was still in danger of collapse. The building was inspected by structural engineers conducting building surveys and safety evaluations of buildings around the WTC site. The building vertical alignment was measured with a transit to determine whether any lateral drift had occurred along the height of the building. Three locations on the west face were evaluated, and no apparent movement was observed in the building. The One Liberty Plaza building was determined to be safe, except for dangers related to broken glass.

Statements were released about the safety of the building, but the rumors persisted on September 13. To stop the rumors and convince the public of the building's safety, DDC surveyors continuously monitored the building and engineers inspected each floor. When a piece of glass fell off One Liberty during the

Figure 7-18 One Liberty Plaza – south elevation, lower floors.

afternoon, it was rumored to be a partial collapse. The findings of the engineers and surveyors concerning the structural safety of One Liberty were reported on the nightly news, and the rumors stopped.

7.9 Observations and Findings

Steel-frame construction from the 1900s through the 1980s, though different in many details, performed well under significant impact loads by limiting impact damage and progressive collapse to local areas.

Heavy unreinforced masonry façades were observed to absorb significant amounts of impact energy in the Verizon and 90 West Street buildings. Heavy masonry façades like those in the Verizon, 90 West Street, or even 130 Cedar Street buildings may also provide an alternative load path for a damaged structure.

Older, early-century fireproofing methods of concrete-, brick-, and terra cotta tile-encased steel frames performed well, even after 90+ years, and protected the 90 West Street building from extensive structural damage.

7.10 Recommendations

The known data and conditions of the perimeter structures after the impact damage should be utilized as a basis for calibration, comparison, and verification of existing software intended to predict such behavior, and for the development of new software for the prediction of the ability of structures to sustain localized and global overload conditions.

7.11 References

Kidder-Parker. 1936. *Kidder-Parker Architects and Builders Handbook*. John Wiley & Sons, Inc. Section on Fire-Resistive Floor Construction.

Figure 7-19
One Liberty Plaza – south elevation, upper floors.

LZA/Thornton-Tomasetti, Guy Nordenson and Associates, and Simpson, Gumpertz, and Heger, Inc. *Interim Life Safety Report, 90 West Street, New York, NY, November 15, 2001*. Prepared for New York City Department of Design and Construction.

LZA/Thornton-Tomasetti and Gilsanz Murray Steficek LLP. *Interim Life Safety Report, 30 West Broadway, New York, NY, November 21, 2001*. Prepared for New York City Department of Design and Construction.

LZA Technology/Thornton-Tomasetti, Structural Engineers Association of New York, and Guy Nordenson, et al., editors. Est. April 2002. *WTC Emergency Damage Assessment of Buildings, Structural Engineers Association of New York Inspections of September and October 2001*. Draft prepared for the New York City Department of Design and Construction. New York, NY.